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Measuring Performance of Replication Mechanisms in Tactical Mobile Environments

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Understanding the problem

- **“The right information to the right place at the right time”**
- Mobile nodes, wireless comms (CNR), low throughput
- Share information, not just data – need to preserve meaning
- Both procedural and technical aspects
- Both info management and distribution aspects
- When pipeline is small, an adaptive response is required
  - changing battlefield situation (C2 node DB)
  - changing state of comms network
- Cooperation between C2 node (application) and comms network required
- **‘Not just a traffic problem’**

Network Topology on the Tactical Battlefield

- Unreliable broadcast medium (radio) provides comms links
- Highly mobile entities participate as nodes on C2 network
- Network of sub-networks; each sub-net on different base frequency
- Nodes frequently connect/disconnect from subnetworks

Data Distribution Requirements

- Autonomous cooperating nodes
  - disconnected operation
- Propagate updates asynchronously on ‘all-informed’ basis
  - profit from (shared) broadcast medium
  - avoid single point of failure
  - change role without substantial one-time data transfer
  - recover data from any node
- Data recovery needs to be carefully managed
- Data conflict avoidance/resolution an important issue
  - role of data ownership
- Negative acknowledgement scheme

‘High Capacity Tactical Communications Network (HCTCN)’ Technology Demonstration

- Aim - Demonstration of selected technologies in the fields of wireless communications and information management
  - increase limited capacity of tactical communications systems to support command and control systems
- Major goals
  - (1) High Capacity Tactical Mobile Radios
    - increase data rate of CNR(P) from 16 kbps to 64 kbps & higher
  - (2) Tactical Networking
    - demonstrate quality-of-service based, self-organizing, self-healing, integrated mobile network
  - (3) Information Management
    - demonstrate adaptive strategies to optimize the flow of information in low bandwidth tactical mobile environment

HCTCN - Information Management

- Development of a low-bandwidth testbed to implement and assess information management strategies
  - contractor - IP Unwired, Ottawa
  - testbed complete - Apr 03
- Tactical Scenario
  - being developed
  - Battle Group command net
- Experimentation program: Apr 03 - Apr 04
- Principal investigators
  - Allan Gibb, Jean-Claude St-Jacques

Concept being demonstrated

How to employ adaptive information management schemes, implemented in digital command and control nodes, to mitigate the effects of

- low bandwidth,

- variable throughput, and

- unreliable connectivity

associated with mobile wireless communication grids.

Information Exchange – Message-Based vs Model-Based Approach

- Structured message approach
  - DB's are repositories for data fields of structured messages; messages must be semantically complete.
  - messages have communication overhead and often some degree of duplication
- Model-based approach
  - DB schema support situational model of battlefield
  - DB entities correspond to battlefield entities
- Exchange DB updates rather than messages

Implementation of Information Exchange using Model-Based Approach

- Database schema which models the battlefield
- Information exchange via DB updates
  - using ‘all-informed’ asynchronous replication scheme
- Active database techniques
  - employ ‘triggers’ and stored procedures to control information flow

Information Management Techniques - Where Implemented

- Can be implemented in *network* layers or *application* layer
- Our project focuses on techniques that can be applied in an *application*, in a *database* on the same node, or in the *middleware* that links the application to the database.

Application Layer Techniques

- Techniques which limit what is transmitted and when it is transmitted
- Techniques which ‘package’ information efficiently

Limiting WHAT is Transmitted and WHEN it is Transmitted

- Automatically assign transmission priority
  - operational context
  - state of communications network
- Minimize sending of duplicate information
  - send only information fields that represent new or changed information
- Intelligent information queueing
  - priority information transmitted first
  - stale information removed from queue

‘Packaging’ Data Efficiently

- Classical data compression techniques
  - alphanumeric
  - video
- Use of lookup tables
  - assign codes to battlefield entities
  - transmit codes
- Transmit DB updates rather than structured messages whenever possible

Data Replication Technologies

- TTCP C3I Group Technical Panel 10 Data Replication Workshop, Fort Leavenworth, KS, Apr 20-22, 1999
- Commercial products designed to serve commercial not military clients
- Light-weight robust support for peer-to-peer replication not yet supported
- Disconnected operation supported, but resynchronization upon reconnection presumes latency not an issue
- Replication that is adaptive to changing network and battlefield conditions not well supported

Why an Information Management Test Bed ?

- Solution to tactical information management is complex
- Need tool for evaluating IM and data distribution strategies
- Techniques adaptive in nature and intended to be applied in tandem
- Not tied to a particular C2IS architecture or system
- Flexibility to explore new IM Techniques and add scenarios
- Evaluate operational impact of adaptive IM Techniques
  - Software ‘switches’ to turn techniques ‘on’ and ‘off’
  - Based on standard scripted scenario(s)
  - Measure, analyze and display results

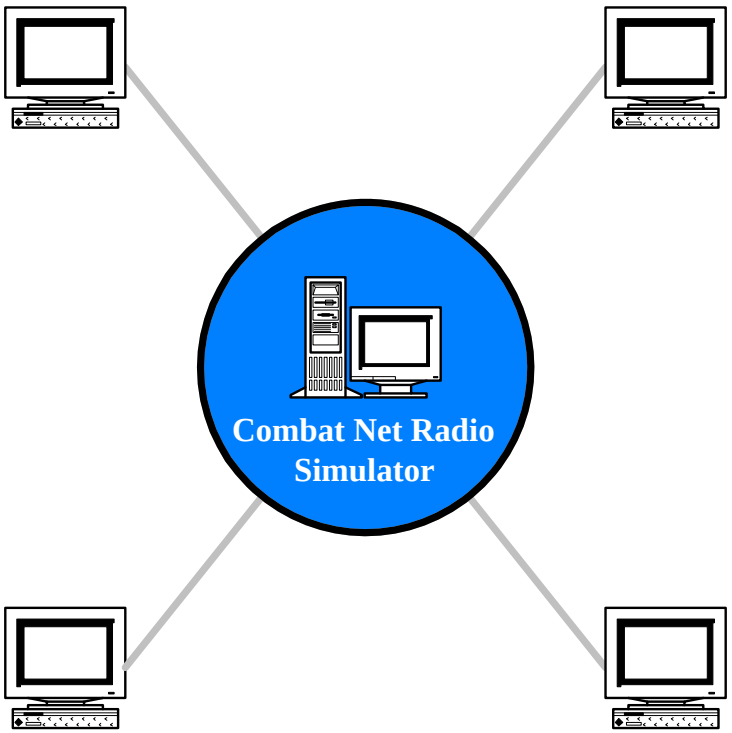
Measurement Philosophy

- Goal: measure operational impact of information management techniques
- Deterministic approach, scripted comms scenario
  1) Execute comms scenario with perfect comms
     - ‘truth’ database
  2) Repeat same scenario with imperfect comms
  3) Repeat same scenario with imperfect comms + information management technique(s) activated
- (1) + (2) = effect of comms system
- (2) + (3) = effect of information management techniques

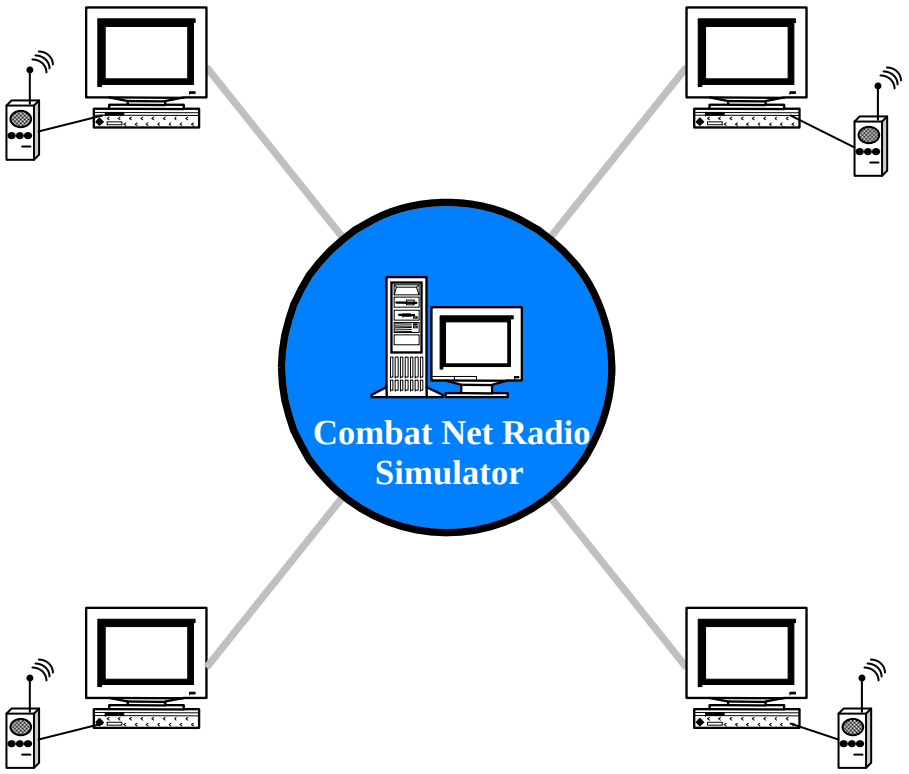
What to Measure

- DB consistency across nodes
- Currency (time since last update)
- Transmission delay
- Quality of information
  - ability of system to preserve throughput of high-value information

Architecture - Mode 1



Architecture – Mode 2



Communication System Simulator – Option 1

- Impose pre-programmed (standard) delay
  - corresponding to background traffic level
  - based on single throughput-delay curve or family of curves derived from OPNET modeling
- Impose ad-hoc (non-standard) delay
  - interrupted transmission
- Block information being passed
  - unsuccessful transmission
    - to all nodes
    - to selected node(s)

Communication System Simulator – Option 2

- Communication model based on Markov process characterization of communication links
  - more realistic characterization of communication channels
  - introduces probabilistic element
  - can model different types of radios

Conclusions

- Measuring performance of replication mechanism in tactical domain involves several factors:
- Faithful simulation of tactical communication system
- Methodology which allows strict control of experimental variables
  - reproducible scenario
  - reproducible comm system performance
  - selectively activate/de-activate IM techniques
- Measurements which reflect effectiveness of replication mechanism in operational terms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